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ANALYZING THE PERFORMANCE PROPERTIES OF BAMBOO TOWELS

HUDA HABIB

Department, of Fashion Design, Arts and Internal Design Collage Umm Al-Qura University,
Makkah, Kingdom of Saudi Arabia

ABSTRACT

Bamboo textile is one of the oldest materials, which have been came under the spot light and has become greatly available selection over the last few years to be used in terry towels, due to its good properties of absorption. It has been studied the effect of some production parameters on the properties of terry towels such as the quality of terry fabrics to meet the required properties at the lowest cost.

In this research nine experimental samples of terry towels fabrics, which differ in the levels of the pile length and pile density were used. The selection of these parameters is because of their effect on the absorption properties of the towel terry fabric.

Results were compared according to standard specification ASTM D5433 to evaluate the quality of terry towel fabrics which produced by bamboo yarns with the previous variables. Results indicated that all the tested samples not only meet the requirements of the standard values of specifications for the properties of durability but also better than them, such as tensile strength in the warp and weft direction and pile withdraw. Also the results achieved acceptable values of the of absorption properties such as vertical wicking of water, spreading of water in horizontal direction, and absorption rate. In addition to that, the hand properties, such as softness, smoothness and drape ability, were compatible with standard specification and the end use. This confirms that every sample which produced in this search achieved all requirements of the standard specification of terry towel and will be suitable for the end use and aftercare processing.

KEYWORDS: Bamboo Textile Fabrics, Towels, Performance Properties, Absorption Properties, Hand Properties, Durability Properties

INTRODUCTION

The primary function of a towel is to absorb moisture from the skin. Therefore it must be soft and absorbent, due to these reasons; bamboo fabric is the suitable for this purpose. Towels are the most textile structures used in water, related to their usage of terry woven fabrics. The users prefer that ready-made bathrobes and towels should to be comfortable and fresh, made of a light and soft structure, remain dry as they quickly transfer the water and sweat accumulated on the body, and be hygienic and naturally formed. The bamboo fibers are selected in this study because of their superior characteristics of water absorption, higher breaking strength, wash ability and softness.

Bamboo yarn has desirable properties, such as good water absorption, bearing in mind that terry materials are widely used for towels, home textile products. Although the raw material is an important parameter in determining the water absorption properties of terry fabrics, pile characteristics also have an effect on them.

The aim of this research is to investigate the water absorption of bamboo terry fabric depending on pile height and pile density. The experimental study will provide a guide for the pile height and pile densities, which suitable for desired properties. The comfort properties of bamboo towel in this research were specific such as water transfer, water absorption, hand evaluation and durability

LITERATURE REVIEW

There are some factors which are important during the production of towels like the selection of the composition of the fibers materials, pile height and density of piles, which they affect the towel properties as wetting and wicking, spreading, water pick up, drying time, water droplet and evaporation [(1)]. The height and the density of the pile form the comfort, but it also affects the wicking rate and absorption [(1)]. An increase in pile height or pile density will give a higher aerial density [(2)]. Higher pile height or loop density will decrease the comfort due to the bending resistance [(3)], but higher density will give higher wicking rate and increase the absorption capacity.

There is a level where the absorption will decrease instead of increase when the pile height is increased. This level depends on yarn number, twist and material [(4)]. The pile height is the most important factor for absorption [(2)]. The material is one of the most important factors for wetting, wicking and absorption.

Cottons fibers advantage is the highest absorption capacity, of the material that used for terry towels, this is due to the hydrophilic, but cottons disadvantage is that the fibers swell of water, the swelling reduces the wicking rate [(1)]. A hydrophobic and hydrophilic fiber can work together. The hydrophilic fabric can absorb the liquid and then the hydrophobic will help the liquid to evaporate [(5)]. Polyester is hydrophobic, the fabric doesn't absorb moisture, but it has very good wicking properties. Nylon has good moisture absorption and good wicking properties, but has a slow drying process. Polypropylene has good wicking properties, but low absorption. The moisture are transported through the fabric instead of absorb in the fabric [(1)]. The available literature on the water absorption properties of terry fabrics which produced from bamboo is limited, and there is a lack of detailed studies on such questions as how the construction of terry fabric affects the water absorption properties of the raw materials.

Absorption properties are determined by the fabric's structure and geometrical characteristics, such as porosity, thickness, pile density, handle.

The high water absorption ability of terry material is due to the loop pile facilitating water absorption, which is thanks to the developed surface [(6)].

The effect of terry fabric parameters on water absorption properties using various fabric constructions without hydrophilic finishes was investigated [(6)]. The percentage of water absorption is the lowest for open-end spinning yarn, and the highest for two-ply ring spinning carded yarn. The higher twist values used in the production of open-end yarns are thought to make water penetration inside open-end yarns more difficult. The pile height together with a large density determines the product's full bulky handle [(7)]. The sorption desorption process is very important to maintain the microclimate during transient conditions [(8)]. The behaviour of textile in contact with liquid plays an important role in determining clothing performance and in maintaining body comfort [(9)].

Fabric hand and drape are two aesthetic fabric properties that have received much attention in textile testing and evaluation. Fabric hand is an individual's response to touch when fabrics are held in the hand. Despite their importance,

these properties are among the hardest to measure, and few standard methods have been developed for determining them. Traditionally, producers, retailers and consumers have evaluated these properties subjectively and by practical experiences [10].

PhabrOmeter system for fabric quality evaluation instrument was developed by Nu Cybertek in USA. It measures drape index, smooth, rough, stiff, soft and others [11]. Also FTT fabric touch tester system is an innovative instrument developed by SDL Atlas is capable of measuring fabric thickness, compression, bending, shearing, surface friction and roughness [12]. It means that these systems make fabric hand and drape measurements available as objective values.

MATERIALS AND METHODS

The raw material of 100 % bamboo was used to produce terry towel, with Ne 24/2 ring spun for ground warp and weft, pile yarn with Ne 20/2 ring spun with low twist rather than ground yarn. A full 3*3 factorial design was conducted to estimate the effects of pile density and pile height on the properties of terry fabric which used as towels. The terry fabrics were woven at three different levels of pile densities and pile height as shown in table 1.

Table 1: Experimental Plan of the Work

Experimental Fabric Nr.	1	2	3	4	5	6	7	8	9
Pile Density / (cm^2)	30	30	30	50	50	50	70	70	70
Pile Height (mm)	3	5	7	3	5	7	3	5	7

Test Methods

Tensile strength in warp and weft direction was tested by Instron tensile testing material according to (ASTMD 5034 grab test) [13]. The size of sample is 100 mm as width and 150 mm as length. Sample was clamped in the jaws, with CRE 300 mm per minute loading and gauge length 75 mm to get tensile strength at break.

Tufts withdraw measures the force required to withdraw a single loop of pile from a terry fabric according to (ISO 4919) [14]. The terry fabric sample is held down by a steel plate, and a pair of surgical forceps is clamped to one end of the tuft to be tested. Tension on the loop is increased and the digital force gauge indicates the maximum force needed to withdraw it. Weight per square meter was tested according to the standard (ASTM D3776) [15].

Moisture management includes three tests as capillary, spreading, and absorbency tests. Capillary test [16] measures the vertical movement of water, which the fabric is suspend vertically so that bottom of fabric is just touching water surface to measure the vertical distance travelled by the water during a set period of time also measure performance in both warp and weft direction. Spreading of water test [17] measures the diameter of water movement across a fabric surface, by applying one millilitre of water and measure the maximum diameter of spread after one minute. In absorbency test method [18], the sample of fabric 10 cm in diameter is placed on to the surface of water in a beaker for 10 seconds, then reweighed accurately to calculate water absorbency or the pickup of water.

Fabric hand was evaluated by PhabrOmeter system [19]. The principle of PhabrOmeter system is insertion and extraction of a piece of circular fabric through nozzle. PhabrOmeter instrument has become a designated machine by AATCC TM202 standard for fabric hand evaluation. A specimen is placed over a plate with a specified diameter opening through which a plunger forces the fabric specimen resulting in mechanical deformation data. Force displacement curve data from a reference fabric and a test fabric are used in calculations to produce drape coefficient; softness index and smoothness index.

The results of all tests were fed to Excel to calculate the regression summery, to determine significant effect between independent parameters and dependant properties.

RESULTS AND DISCUSSIONS

Statistical Data Analysis

Evaluation of the test results was made by using Excel program. The results were statistically analyzed by (ANOVA) with a confidence level of 95%, the statistical significance of towel properties was explained in tables 2, 3, and 4.

Table 2: Effect of Pile Height and Pile Density on Durability Properties

	Tensile Strength in Warp Direction		Tensile Strength in Weft Direction		Pile Withdraw	
Parameters	t - Stat.	P-Value	t - Stat.	P-Value	t - Stat.	P-Value
Pile Density	4.787	0.003	3.719	0.010	0.000	1.000
Pile Height	-4.717	0.003	-6.031	0.001	-82.731	0.000

It is clear from table 2 that P-values for pile density and pile height 0.003 and 0.003 respectively, it means that they have significant effect on tensile strength in warp direction, and P-values for pile density and pile height 0.01 and 0.001 respectively, this means that they have significant effect on tensile strength in weft direction, also P-value for pile density 1, it means that it is has no significant effect on pile withdraw, but P-value of pile height 0.00, it means that it has significance effect on pile withdraw.

Table 3: Effect of Pile Height and Pile Density on Fabric Hand

	Softness Index		Smoothness Index		Drape Index	
Parameters	t - Stat.	P-Value	t - Stat.	P-Value	t - Stat.	P-Value
Pile Density	-10.281	0.000	12.903	0.000	11.076	0.000
Pile Height	-3.367	0.015	-6.486	0.001	3.826	0.009

Results in table 3 clarified that P-values for pile density and pile height 0.00 and 0.015 respectively, this means that they have significant effect on towel soft, and P-values for pile density and pile height 0.00 and 0.001 respectively, it means that they have significant effect on towel smooth. P-values for pile density and pile height 0.00 and 0.009 respectively, this means that they have significant effect on Drape ability of towel.

Table 4: Effect of Pile Height and Pile Density on Moisture Management

	Wicking Vertical		Spreading Horizontal		Water Absorption	
Parameters	t - Stat.	P-Value	t - Stat.	P-Value	t - Stat.	P-Value
Pile Density	-6.708	0.001	-3.128	0.020	22.613	0.000
Pile Height	-9.391	0.000	-6.881	0.000	13.568	0.000

Table 4 presents P-values for pile density and pile height 0.001 and 0.00 respectively, it means that they have significant effect on wicking in vertical direction, and P-values for pile density and pile height 0.02 and 0.00 respectively, this means that they have significant effect on spreading in horizontal direction, also P-values for pile density and pile height 0.00 and 0.00 respectively, it means that they have significant effect on water absorption.

Durability Properties

Durability properties consist of tensile strength in warp and weft direction and pile withdraw that will be discussed in the following.

Tensile Strength in Warp Direction for Bamboo Towels

Most of researchers are interested only the property of absorption for towel fabric, but this search is interested to meet all requirements of ASTM specification D5433 standard performance [20] specification, which covers the evaluation of hand towel and bath towel products for institutional and household, as properties of durability (tensile strength in warp and weft, pile withdraw), properties of hand evaluation (drape, softness and smoothness) and properties of moisture management (capillary, spreading and absorption).

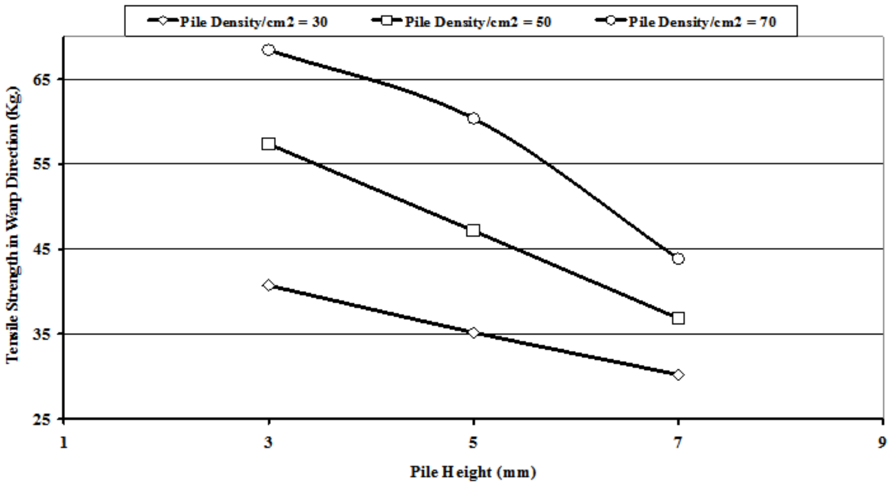

Figure 1: Relation between Pile Height and Tensile Strength in Warp Direction at three levels of pile density

Despite of moisture absorption property is very important, but it should not be the only worthy property of interest to the researchers, where there are other properties of the great importance of towels made of terry fabrics, because they are exposed to various stresses during the end-use and aftercare. Terry towel fabrics are exposed to mechanical stresses during after care processes as tensile strength bending stresses, friction and pilling during washing and drying, which required to meeting the minimum limits of standard speciation of performance during end use.

Figure 1 illustrates the relationship between pile height and pile density on tensile strength in warp direction. First of all the results of this terry fabric achieved the requirements of durability for tensile strength in warp and weft direction, which the minimum tensile strength in warp direction 302.3 N while the requirements in ASTM D5433 is 178 N. this leads to be acceptable during end use depending on the standard specification, the maximum tensile strength in warp direction 684.5 N. Also minimum tensile strength in weft direction 162.9 N while the requirements in ASTM D5433 is 133 N. this leads to be acceptable during end use depending on the standard specification , the maximum tensile strength in weft direction 397.3 N.

Tensile Strength in Weft Direction for Bamboo Towels

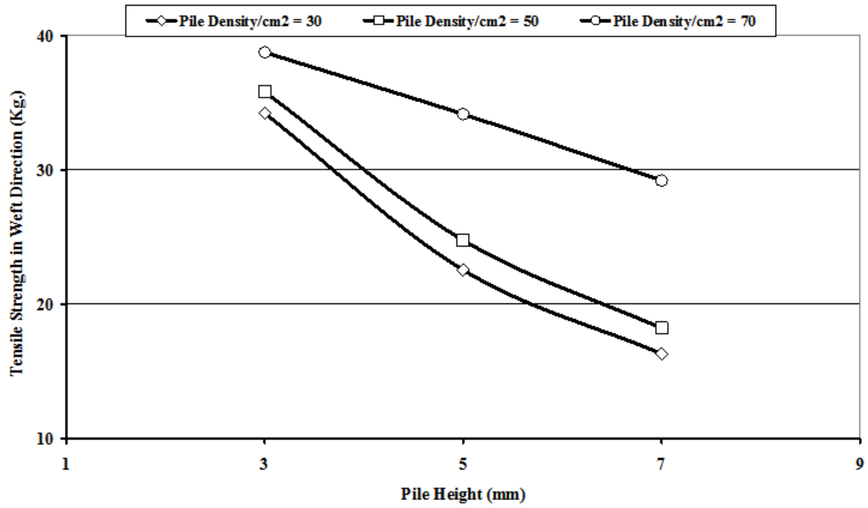

Figure 2: Relation between Pile Height and Tensile Strength in Weft Direction at Different Levels of Pile Density

It is clear that in figures 1 and 2, that all samples which produced in this research with the experimental design have achieved more than the requirements and for the specification of the performance of the cloth terry towels. The high densities of pile has achieved high tensile strength in warp and weft direction rather than the low pile densities due to the contribution of pile yarns with ground yarn to distribute the tensile stresses during test and therefore during end use.

Pile Withdraw

Pile yarn seems to be visible and apparent on the surface of terry towel fabric, so it is exposed to withdraw and deform during end use and by interlacing during aftercare processing rather than the ground yarn of terry fabric. Therefore, the pile yarn must meet the minimum requirements of specification

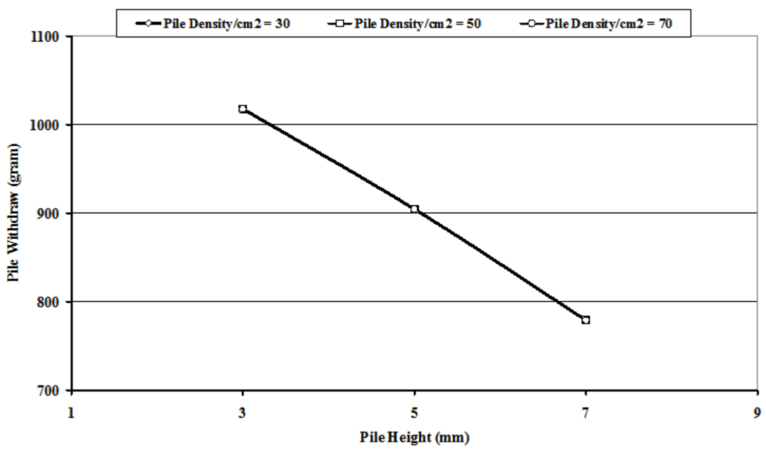

Figure 3: Relation between Pile Height and Pile Withdraw at Different Levels of Pile Density

Figure 3 illustrates the relationship between pile withdraw and pile height at three levels of pile densities, it seems that the relation is inverse between them, with the increasing of pile yarn height, the weak points of yarn will increase,

which lead to decrease the pile withdraw. Otherwise, with the decrement of pile yarn height, the weak points of yarn will decrease, which leads to increase the force of pile withdraw.

It is noted that pile withdraw is constant at three levels of pile density, and all results are plotted over them for all pile densities, where the statistical analysis impressive that pile density has no significant on pile withdraw as shown in table (2).

Fabric Hand Evaluation Softness, Smoothness and Drape

Fabric hand and drape properties consist of softness index, smoothness index and drape index which discussed as following.

Towel softness is related to towel thickness and it is directly related to how easily to compress the fabric under pressure. Towel with high density and pile height will give a thicker and bulker fabric.

Softness Index

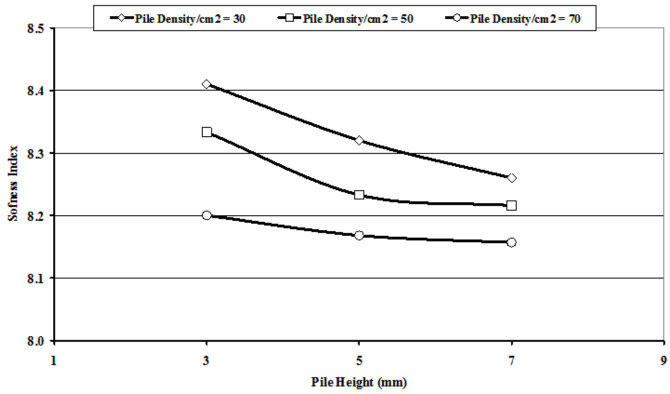

Figure 4: Softness Index of Terry Towel Fabric

Smoothness Index

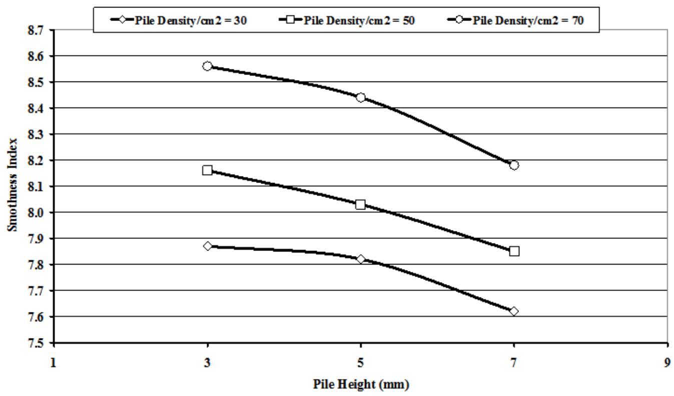

Figure 5: Smoothness Index of Terry Towel Fabric

Figures 4 and 5 illustrate the relationship between softness index and smoothness index and pile heights at different pile densities.

For a fabric hand values as softness index smoothness index, it is clear from the previous figures, that an increasing the pile height, decrease the soft and smooth index, i.e. the soft and smooth touch of towel will improve. With the increasing of pile height and density, towel fabric gives a better hand values, because towel fabric formed balance structure which lead to a flat and soft and smooth surface of towel fabric.

Drape Index

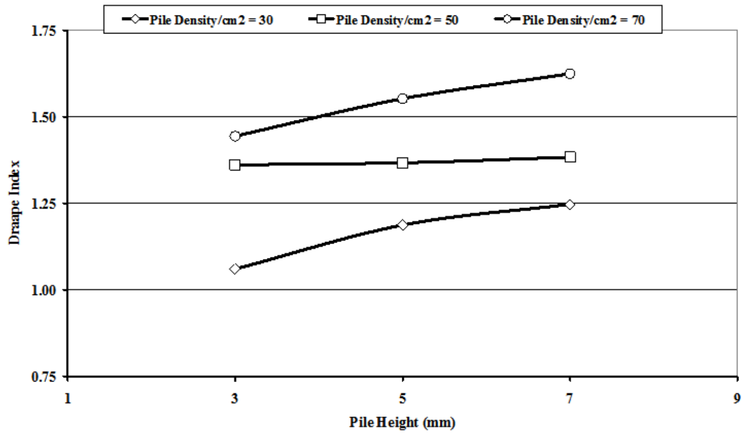

Figure 6: Drape Index of Terry Towel Fabric

The importance of fabric drape is almost self evident**,** by decreasing pile density and pile height, towel fabrics have better draping (smaller value) as shown in figure (6) because the fabric is lighter in weight and thinner in fabric thickness.

Moisture Management

Moisture management properties consist of wicking of water in vertical direction, spreading of water in horizontal direction and water absorption that will be discussed in the following.

Wicking of Water in Vertical

Water transport which occurs through the capillaries is called wicking. In wicking, water is transported due to the capillaries present in the fabrics and water is stored in the capillaries that are formed between fibers and yarns. The material is one of the most important factors for wetting, wicking and absorption.

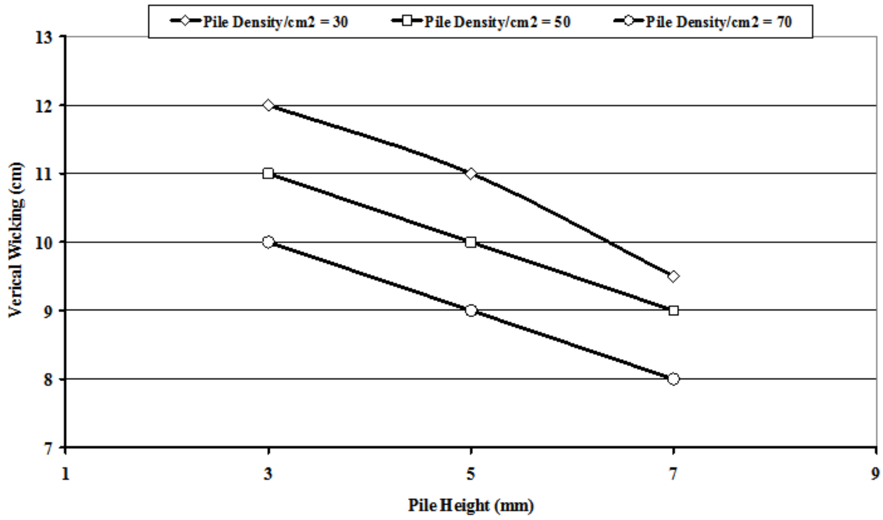

Figure 7: Relationship between Pile Heights and Vertical Wicking of Water at Three Levels of Pile Densities of Bamboo Towel

Moisture is transported vertically in bamboo fiber through capillary action or wicking, because of the spaces between the fibers of bamboo effectively form tubes due to the cross section of bamboo fibers, which act as capillaries, and transport the water away from the surface. Figure 7 points, that by increasing pile height, the time of transport moisture to the outer surface will increase, so that the short pile has wicking better than long pile.

By increasing the pile density, will increase vertical wicking because of more water absorbency so more high capillary pressure and therefore faster wicking in vertical direction will increase. As a rule, the narrower the spaces between the fibers in bamboo fabric, the more effectively they will draw up moisture. For this reason, bamboo fabrics with many narrow capillaries, such as microfibers, are ideal for moisture transport.

Spreading in Horizontal Direction

Figure 8 illustrates relation between spreading of water in horizontal direction and pile heights at different levels of pile density. It is clear that water is transported horizontally in bamboo terry fabric depending on cellulosic bamboo properties and spaces between fibers. An increasing of pile height, the time of water transport horizontally will increase, so that the short pile has spreading effect better than long pile. By increasing the pile density, will decrease spreading of water, because of more water absorbency, and pile density will resist and prevent the water flow in horizontal direction.

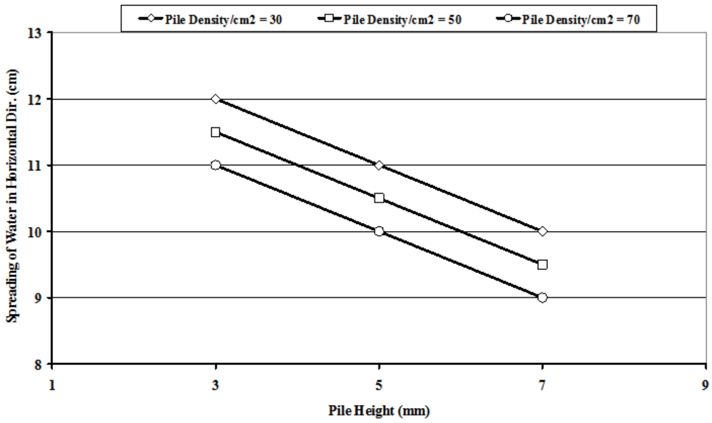

Figure 8: Relationship between Pile Heights and Spreading of Water in Horizontal Direction, at three Levels of Pile Densities of Bamboo Towel

Absorption of Water

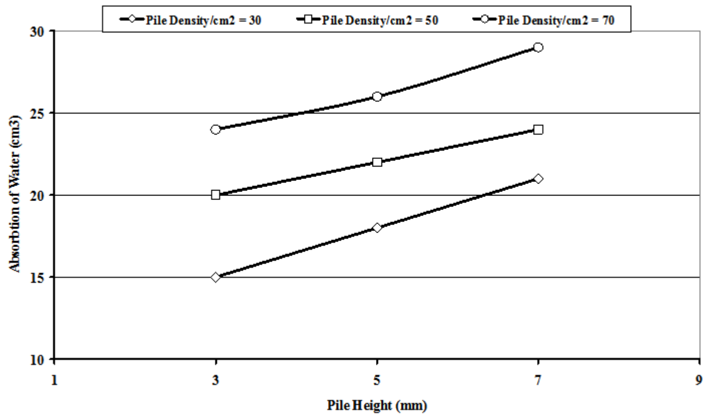

Figure 9: Relationship between Pile Heights and Liquid Absorption at Three Levels of Pile Densities of Pile of Bamboo Towel

Figure 9 shows that the rate of absorption of liquids by fabrics is affected by the nature and size of the small capillaries present in bamboo fabric. It was found that an increase in pile height of towels leads to an increase of absorption rate of liquid for all pile densities. By increasing pile height the surface area of pile yarns will increase, which will be able to absorb more water. Also it was found that increasing the pile density causes also increasing the water absorption; due to the terry fabric has the ability to pick up more water. By increasing the pile density, will increase water absorption, because pile yarns have more surface area to absorb water due to their bulk.

CONCLUSIONS

- Pile density may to increase tensile strength in warp and weft direction because of its contribution with ground yarn, but pile density has no significant effect on pile withdraw.
- An increasing of pile height and density of towel fabric forms balance structure which lead to a flat and soft and smooth surface.
- Height of pile and density of pile play an important role to improve quality of terry towels and achieve the

appropriate quality with economical price.

- Water absorption is not the only property that should be used to evaluate towel quality, but durability and fabric hand properties must be considered as requirements of evaluation.
- Moisture management as wicking, spreading and absorption affected by the cellulosic properties of bamboo fiber.

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